Integrating tuProlog into DCaseLP to Engineer Heterogeneous Agent Systems[⋆]

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Abstract. This paper discusses the integration of a Prolog implementation, tuProlog, into the DCaseLP environment for building prototypes of multi-agent systems (MASs). DCaseLP aims at providing the MAS developer with a plethora of specification and implementation languages in order to allow him/her to adopt the best language for each view of the system under specification/implementation. The integration of tuProlog into DCaseLP represents a step forward in this direction and allows the re-use of tools and mechanisms previously developed for the DCaseLP predecessor, CaseLP.

1 Introduction

Multiagent Systems (MASs) involve heterogeneous components which have different ways of representing their knowledge about the world, about themselves, and about other agents, and which adopt different mechanisms for reasoning about this knowledge. Despite heterogeneity, agents need to interact and exchange information in order to cooperate or compete for the control of shared resources; this interaction may follow sophisticated communication protocols.

For these reasons and due to the complexity of agents behaviour, MASs are difficult to be correctly and efficiently engineered. Even developing a working prototype may require a long time and a lot of different skills. In fact, the prototype can involve agents that would be better modelled and implemented by means of a language based on Horn clauses, agents that would be easily defined using an expert system-like language, and others that should be directly implemented in some implementation language, in order to access existing software packages or the web. Moreover, some general aspects of the MAS can be better specified with ad-hoc specification languages. For example, the MAS architecture, the internal agent architecture and the interaction protocols among agents can be easily specified using graphical tools and languages.

The development of a prototype system of heterogeneous agents can be carried on in different ways. A first -trivial- solution consists of developing all the agents by means of the same implementation language and to execute the obtained program. If this approach is adopted, during the specification stage it would be natural to select a specification language that can be either directly executed or easily translated into code, and to specify all the agents in the MAS using it. An opposite solution would

[⋆] Parts of this document appear in [5].

be to specify each “view” of the MAS (including the MAS architecture, the interaction protocols among agents, the internal architecture and functioning of each agent) using the most suitable language capable to deal with the MAS’s peculiar features, and to verify, execute, or animate the obtained specifications inside an integrated environment. Such an environment should offer the means to select the proper specification language for each view of the MAS, and to check the specifications. This check may be carried out thanks to formal validation and verification methods or by producing an executable code and running the prototype thus obtained.

Despite its greater complexity, the last solution has many advantages over the first, trivial one.

1. By allowing the use of different specification languages for each view of the MAS, *it supports the progressive refinement of specifications*: for example, the specification of an interaction protocol performed during the early analysis stage does not need to be as detailed as the complete specification of an agent performed during the design stage; details can be progressively added while the engineering process goes on.
2. By allowing the use of different specification languages for the internal architecture and functioning of each agent, *it respects the differences existing among agents*, namely the way they reason and the way they represent their knowledge, the other agents, and the world.
3. By allowing different implementation languages to be integrated inside the same running prototype, *it allows the direct implementation of some of the agents*, skipping the specification stage.
4. In case more than one language fits the requirements of an agent/view under specification, *it allows the developer to choose the language he/she knows best and likes*, thus leading to more reliable specifications and implementations.

Currently, solid and complete environments that allow the integration of heterogeneous specification and implementation languages in a seamless way do not exist yet, but some preliminary steps have been made in this direction, and some initial results have already been achieved with the development of prototypical environments for engineering heterogeneous agents. DCaseLP (Distributed CaseLP), integrates a set of specification and implementation languages in order to model and prototype MASs and defines a methodology which covers the engineering stages from requirements analysis to prototype execution, which relies on the use of AUML (Agent UML, [14]) both at the requirement analysis level and for describing the *interaction protocols* followed by the agents. Although the first release of DCaseLP [12,1] demonstrates that the concepts underlying the “integrated environment for engineering heterogeneous MAS” can be put into practice and can give interesting results, it suffers from two limitations that affect its applicability:

1. it does not provide the means to re-use the code and instruments already developed for the predecessor of DCaseLP, CaseLP [13]; and
2. it does not provide tools and languages for reasoning about properties of the interactions occurring among the agents.

The last limitation can be addressed by translating AUML interaction protocols into the DyLOG language [8,4,6], and then integrating DyLOG into DCaseLP. The exploitation of DyLOG to address the problems of protocol selection, composition and implementation conformance w.r.t. an AUML sequence diagram is dealt with in [7], while the integration of DyLOG into DCaseLP is discussed in [5].

The first limitation can be overcome by extending DCaseLP with the ability to integrate agents specified as Prolog theories, as shown in this paper.

The structure of the paper is the following: Section 2 overviews the DCaseLP environment and discusses the outcomes of integrating an existing Prolog implementation, tuProlog, into DCaseLP, while Section 3 discusses the technical details of this integration. Section 4 shows an example of use of DCaseLP extended by tuProlog; conclusions follow.

2 The DCaseLP environment

DCaseLP is a prototyping environment where agents specified and implemented in a given (and fairly limited!) set of languages can be seamlessly integrated. DCaseLP provides an agent-oriented software engineering methodology to guide the MAS developer during the analysis of the MAS requirements, the MAS design, and the development of a working MAS prototype. The methodology is shown in Figure 1. Solid arrows represent the information flow from one step to the next one. Dotted arrows represent the iterative refinement of previous choices. The first release of DCaseLP did not deal with all the stages of the methodology. In particular, the verification stage was not addressed. In the same way as the integration of DyLOG into DCaseLP will allow us to formally verify properties of communication protocols, the integration of tuProlog into DCaseLP discussed in Section 3 will allow us to address the verification phase by re-using the verification mechanisms developed for CaseLP ([13], Sections 3.3 and 4.4).

DCaseLP is the result of the effort to re-implement CaseLP [13] in order to overcome its main limitations, namely:

1. its centralization,
2. its poor support to concurrency, and
3. its lack of adherence to existing standards.

The tools and languages supported by the first release of DCaseLP, discussed in [12,1], are represented in Figure 2 by means of the darker boxes. Lighter boxes represent the desired extensions in respect to that release. Some of these extensions have already been made, while some are currently being made, and some others are just part of our future work.

DCaseLP adopts an existing multiview, use-case driven and UML-based method [2,3] in the phase of requirements analysis.

Once the requirements of the application have been clearly identified, the developer can use UML and its agent-oriented extension AUML to describe the interaction protocols followed by the agents, the general MAS architecture and the agent classes and instances. Moreover, the developer can also automatically create the rule-based code for the agents in the MAS in such a way that the UML/AUML specification is satisfied.

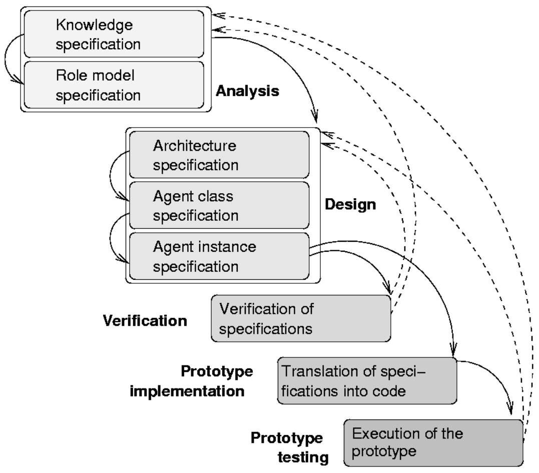

Knowledge specification
Role model specification
Analysis
Architecture specification
Agent class specification
Agent instance specification
Design
Verification
Verification of specifications
Prototype implementation
Translation of speci–fications into code
Prototype testing
Execution of the prototype

Fig. 1. DCaseLP methodology.

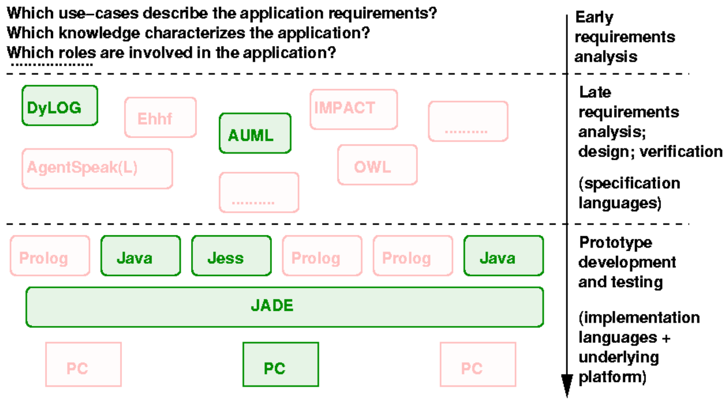

Which use–cases describe the application requirements?
Which knowledge characterizes the application?
Which roles are involved in the application?
Early requirements analysis
DyLOG
Ehhf
AUML
IMPACT
....
AgentSpeak(L)
....
OWL
Late requirements analysis; design; verification
(specification languages)
Prolog
Java
Jess
Prolog
Prolog
Java
JADE
PC
PC
PC
Prototype development and testing
(implementation languages + underlying platform)

Fig. 2. Tools and languages supported by DCaseLP, first release.

In the following, we will assume to use AUML during the requirements analysis stage, although the translation from AUML into rule-based code is not fully automated (while the translation from pure UML into code is).

The rule-based language used for the implementation of DCaseLP agents is Jess [11]. The Jess code obtained from the translation of AUML diagrams must be manually completed by the developer with the behavioural knowledge which was not explicitly provided at the specification level. On the one hand, the developer does not need a deep insight in rule-based languages in order to complete the Jess code, since he/she is guided by comments included in the automatically generated code. In this way, a developer who is not confident with rule-based languages can concentrate on the AUML specification and make a little effort to complete the rule-based code in order to make it executable. On the other hand, the developer who prefers to define agents in a declarative language can skip the AUML specification stage and directly write the Jess code.

The choice of Jess as the language for implementing agents was lead by two considerations:

1. being a rule-based language, Jess is suitable for representing both the event-driven and the goal-driven behaviours of the agents;
2. being implemented in Java, Jess can be easily integrated into the FIPA-compliant JADE platform.

JADE (Java Agent Development Framework, [9]) provides both a middle-ware that complies with the FIPA specifications [10] and a set of graphical tools that support the debugging and deployment phases. The agents can be distributed across several machines and they can run concurrently. The adoption of JADE as the underlying platform for implementing DCaseLP was a must in order to overcome the three limitations of CaseLP. In fact, JADE is distributed, allows the concurrent execution of agents, and is FIPA-compliant. By integrating Jess into JADE, we were able to easily monitor and debug the execution of Jess agents thanks to the monitoring facilities that JADE provides. The experiments carried out with the first release of DCaseLP were on a single machine (see Figure 2: there is only one dark box labelled with “PC” under the JADE box).

The possibility of running the prototype allowed the first release of DCaseLP to demonstrate its ability in checking the coherence of the AUML diagrams produced during the requirements analysis step. Performing such a check is a well known and still open problem that we could face without additional effort. Nevertheless, that release still suffered from one limitation: it was not able to integrate any Prolog implementation. The predecessor of DCaseLP, namely CaseLP, is implemented in Sicstus Prolog [15], and a lot of work has been done to study and define semi-automatic translators from high-level specification languages into CaseLP agents, namely agents described in Sicstus Prolog extended with communication primitives. Limited support to formal verification of specifications – completely missing in DCaseLP – is indeed provided by CaseLP. Without the integration of Prolog into DCaseLP, all that work would have been lost. Recently, we have extended DCaseLP with the ability to integrate agents specified as Prolog theories. Section 3 discusses how we have integrated an existing Prolog implementation, tuProlog [16], into DCaseLP. The choice of tuProlog was due to two of its features:

1. it is implemented in Java, which makes its integration into JADE easier, and
2. it is very light, which ensures a certain level of efficiency to the prototype.

The integration of tuProlog into DCaseLP has been completed very recently. Due to the syntactic differences existing between Sicstus Prolog and tuProlog, CaseLP agents specified using Sicstus Prolog cannot be simply treated as if they were DCaseLP agents specified using tuProlog: a translation step from "Sicstus Prolog for CaseLP agents" to "tuProlog for DCaseLP agents" is necessary. We guess that this translation step can be easily automatised, thus allowing us to re-use the tools developed for CaseLP inside DCaseLP; however, its implementation has not been completed due to lack of time. Again due to time limitations, we did not verify the ability to run JADE, Jess and tuProlog agents as part of the same, heterogeneous, MAS. At the time of writing, we have only developed some examples (one of which is discussed in Section 4) that demonstrate that tuProlog agents are able to interact with both tuProlog and JADE agents by taking advantage of the underlying communication middle-ware provided by JADE, and that the execution of the resulting MAS can be monitored using the tools offered by JADE. When the translator "*Sicstus Prolog* $\rightarrow$ *tuProlog*" will be ready, and when the compatibility between Jess and tuProlog agents will be fully established, DCaseLP will be closer than now to the integrated environment for engineering heterogeneous MASs envisaged in Section 1. In particular,

1. *It will support the progressive refinement of specifications*: for example, the interactions among agents belonging to the MAS and among internal components of the same agent will be specified in some suitable language (AUML, other languages provided by CaseLP), will be then formally verified, and will be finally implemented by adding all the details needed by the MAS or by the single agent to work.
2. *It will respect the differences existing among agents*: an agent which reasons in a goal-driven, backward fashion will be easily defined by means of a tuProlog theory; a rule-based agent will be better defined using Jess.
3. *It will allow the direct implementation of some of the agents*: JADE agents are basically Java agents and thus they are implemented agents, rather than specified agents.
4. *It will allow the developer to choose the language he/she knows best and likes*: it will provide a bunch of languages to choose from.

3 Integrating tuProlog into DCaseLP

The integration of tuProlog into DCaseLP has been carried out in order to provide the developer of the MAS with a means to define the behaviour of an agent by using another declarative language besides Jess, and to re-use the code and instruments previously developed for CaseLP. To do so, tuProlog has been integrated into JADE.

JADE includes a specific package to develop Java agents and a programmer's guide containing implementation guidelines that the developer should follow to code his/her agents in Java. Any Java class that extends the class `Agent` defined in the package `jade.core` of JADE can be considered as a JADE agent. To add tuProlog in DCaseLP, three Java classes have been defined in a package named `tuPInJADE`:

1. the class `JadeShell42P`, which represents a tuProlog agent in JADE;
2. the class `JadeShell42PGui` that provides an additional GUI at the loading of the agent; and
3. the class `TuJadeLibrary`, which is a tuProlog library (developed in Java) necessary to a tuProlog agent in order to communicate in the JADE platform.

As the name of the class suggests, `JadeShell42P` behaves as a shell for a tuProlog engine. To execute a `JadeShell42P` agent in JADE, the programmer has to give, in input, the name of a file containing a tuProlog theory that represents the behaviour of the agent (Figure 3). The class `JadeShell42PGui` differs from class

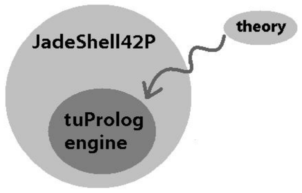


Fig. 3. JADE shell for a tuProlog engine.

`JadeShell42P` in the fact that, when loaded into JADE, it does not need the name of the theory file in the command line: it loads the pop-up window shown in Figure 4 with which the user can browse the file system and select from the list of files the one defining a tuProlog theory to be used as behaviour of the agent. Such a tuProlog the-

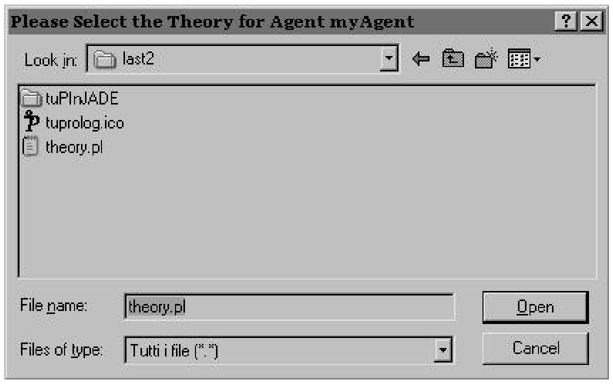
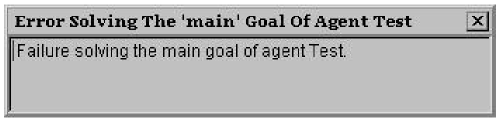

Please Select the Theory for Agent myAgent
Look in: last2
tuPInJADE
tuprolog.ico
theory.pl
File name: theory.pl
Files of type: Tutti i file (*.*)
Open
Cancel

Fig. 4. Window for theory selection.

ory file has only one restriction: it has to begin with the definition of a predicate called main/0. When a tuProlog agent is loaded into JADE, it first creates a tuProlog engine that supports the standard tuProlog libraries and then extends them by loading the ad-hoc tuProlog library named TuJadeLibrary. The behaviour of any tuProlog agent is to use the tuProlog engine, created during its initialisation phase, to always solve the predicate main. A typical main predicate calls predicates to read a new message, handle it and carry out some actions such as update of the agent's knowledge and message delivery.

The goal's demonstration is not visible to the programmer: if he/she wants to be informed of the variable's bindings made during resolution, he/she has to explicitly write the variables on the standard output or in some files that he/she can subsequently go to and read. The only explicit information which is provided for the user regards the failure of the goal's demonstration and other situations which raise an error during the resolution process. To make this information visible, the package tuPInJADE defines the Java class ErrorMsg, that is used by the tuProlog agents as a pop-up window displaying error and failure messages, like the one shown in Figure 5. The


Error Solving The 'main' Goal Of Agent Test

Failure solving the main goal of agent Test.

Fig. 5. Window for error and failure messages.

Java class JadeShell42P defines the inner class Shell42PBehaviour (named Shell42PBehaviourGui in the class JadeShell42PGui) that extends the Java class CyclicBehaviour defined in the package jade.core.behaviours of JADE.

Shell42PBehaviour implements the only behaviour of a JadeShell42P agent: every time the agent is scheduled by the JADE's scheduler, it tries to fulfill only one activity, that is, the resolution of the goal main. The Shell42PBehaviour models a cyclic task and cannot be interrupted while executing its action method. The result is the same as if the agent performed a "while true do main" statement, with main being dealt with as an atomic action.

The Java class TuJadeLibrary is the core class dealing with communication of tuProlog agents in JADE. This library defines the predicates send and receive: they are the directives implementing the sending and receiving of the FIPA compliant and asynchronous messages to and from agents of a JADE platform. The send and receive predicates simply invoke the send and receive methods of a JADE agent, therefore they not only allow communication among tuProlog agents but also among ordinary JADE agents and tuProlog agents.

The arguments of the send predicate are: the performative, the content and the JADE address/list of addresses of the receiver/receivers of the message. The arguments of the receive predicate are: the performative, the content and the JADE address of the sender of the message. Actually, since JADE agents have the possibility to stop their activity while waiting for a message to arrive in their messages queue, the TuJadeLibrary also defines two blocking_receive predicates: one without a timeout and the other with a timeout. These predicates correspond to the blockingReceive method of an ordinary JADE agent.

Finally, TuJadeLibrary defines two predicates for converting strings into terms and vice-versa, named pack and unpack. They allow tuProlog agents to send strings as the content of their messages, and to reason over them as if they were tuProlog terms.

4 Example

To show how DCaseLP can be used to develop a working MAS prototype, we use a simple example drawn from a distributed marketplace scenario.

In such a marketplace, there are two agents (buyer1 and buyer2) that want to buy some fruit (oranges, apples and kiwi) from three agents (seller, seller1 and seller2). Agents buyer1, buyer2, seller1 and seller2 are all tuProlog agents, while seller is an ordinary JADE agent.

The agents that sell fruit can receive two kinds of FIPA ACL messages from the buyers:

1. a request for price: the message received has the performative REQUEST and the content price(Fruit), where Fruit is oranges or apples or kiwi;
2. a request for buying: the message received has the performative REQUEST and the content buy(Fruit, Amount), where Fruit is oranges or apples or kiwi, while Amount is the quantity of fruit that the buyer wants to buy.

A seller replies to a price request made by a buyer by sending an INFORM message that has the content price(Fruit, Price), where Fruit is oranges or apples or kiwi and Price is the corresponding price.

The reply to a request for buying depends on whether or not the seller has enough fruit to sell: in case the quantity of fruit that the buyer is willing to buy is less or equal to the one possessed by the seller, the seller will send the buyer an INFORM message with the content bought(Fruit), to inform the buyer that the fruit Fruit has been sold. On the other hand, if the seller does not own enough fruit, it sends the buyer an INFORM message with the content no_more(Fruit), so the buyer will know it can no longer buy Fruit from that seller.

At the beginning, the buyers send a request for the price of all the fruit to all the sellers. Once they know the prices of the fruit, they send requests for buying fruit to the agents that sell it at the cheapest price. The buyers keep sending messages requesting to buy fruit while they still have money and the sellers have enough fruit to sell.

To give the flavor of how a tuProlog agent looks like, the code below shows a piece of the tuProlog theory defining the behaviour of buyer1.

```
main :-
  handle_msgs,
  ask_prices,
  buy_goods.
```

```
goods_possessed(oranges, 0) :- true.
goods_possessed(apples, 0) :- true.
goods_possessed(kiwi, 0) :- true.

buys(goods(oranges), quantity(2)) :- true.
buys(goods(apples), quantity(3)) :- true.
buys(goods(kiwi), quantity(12)) :- true.

money(200) :- true.

sellers_addresses(["seller1@gruppoai:1099/JADE",
             "seller2@gruppoai:1099/JADE",
             "seller@gruppoai:1099/JADE"]) :- true.

.............

handle_msgs :-
  receive(Performative, Message, Sender),
  select(Performative, Message, Sender).

select(Performative, Message, Sender) :-
  bound(Performative),
  bound(Message),
  address_name(Sender, Name),
  unpack(Message,TermMsg),
  handle(Performative, TermMsg, Sender).

select(_, _, _) :- true.

handle("INFORM",
      bought(Goods),
      Sender) :-
  bound(Goods),
  address_name(Sender,S),
  price(S,Goods,P),
  retract(money(M)),
  retract(goods_possessed(Goods,X)),
  buys(goods(Goods),quantity(Q)),
  N is X + Q,
  P \= na,
  NM is M - P,
  assert(money(NM)),
  assert(goods_possessed(Goods,N)).
```

The `main` predicate defines three activities which consist in handling incoming messages, asking the price of fruit from sellers (only at the beginning, when the buyer does not yet know the prices) and buying fruit. After defining the `main` predicate, the theory declares the initial state of the buyer: `buyer1` possesses no fruit, buys oranges in stocks of 2 kilograms, apples in stocks of 3 kilograms and kiwi in stocks of 12 kilograms, and has 200 Euro to spend. The list of addresses of the sellers follows (`sellers_addresses`), together with other information not relevant in this context.

The handling of messages consists of receiving one message (calling the `receive` predicate provided by the `TuJadeLibrary` and introduced in Section 3) and transforming its content, which is a string, into a tuProlog term (calling the user-defined predicate `select`). The `select` predicate calls the `unpack` predicate provided by the `TuJadeLibrary` in order to transform the string that represents the content of the message into a term, and then it calls the user-defined `handle` predicate on the performative of the message, the obtained term, and the sender of the message.

In the example considered, a buyer receives a message whose content is the string `bought(Goods)`. The buyer knows the price of `Goods` (by solving the goal `price(S, Goods,P)`) and it knows the quantity of `Goods` it bought (by solving the goal `buys(goods(Goods),quantity(Q))`). Having succeeded in buying `Goods`, the buyer must update both the possessed amount of `Goods` and the remaining money (calls to standard Prolog predicates `retract`, `is` and `assert`). Similar definitions of the predicate `handle` are provided for any other message that the buyer may receive.

The ordinary JADE agent, `seller`, is characterised by a Java code partly shown below.

```
package tuPInJADE;

import jade.core.Agent;
import jade.core.AID;
import jade.core.behaviours.CyclicBehaviour;
import jade.lang.acl.ACLMessage;

public class Seller extends Agent
  { private int orangesAmount = 5;
   private int applesAmount = 5;
   private int kiwiAmount = 10;
   private int orangesPrice = 105;
   private int applesPrice = 80;
   private int kiwiPrice = 100;

  protected void setup()
        { SellBehaviour p = new SellBehaviour(this);
        addBehaviour(p);
        }}

class SellBehaviour extends CyclicBehaviour
```

```
{ private static boolean done = false;

public SellBehaviour(Agent a)
     { super(a); }

public void action()
     { ACLMessage msg;
     while (!done)
     { msg = myAgent.receive();
     if (msg != null) handleMsgs(msg);}}
```

The `Seller` class extends the JADE `Agent` class as any agent running in JADE must do. The behaviour of the seller is a cyclic behaviour (class `SellBehaviour` extends `CyclicBehaviour`) which continuously checks for a message (`msg = myAgent.receive()`) and, if a message is present, handles it (`if (msg != null) handleMsgs(msg)`).

Once all the agents have been specified using tuProlog or JADE, they can be loaded into JADE and the execution of the obtained prototype can start. JADE offers the possibility to follow the communication between the agents by means of the “sniffer” agent which is a GUI whose output is shown in Figure 6.

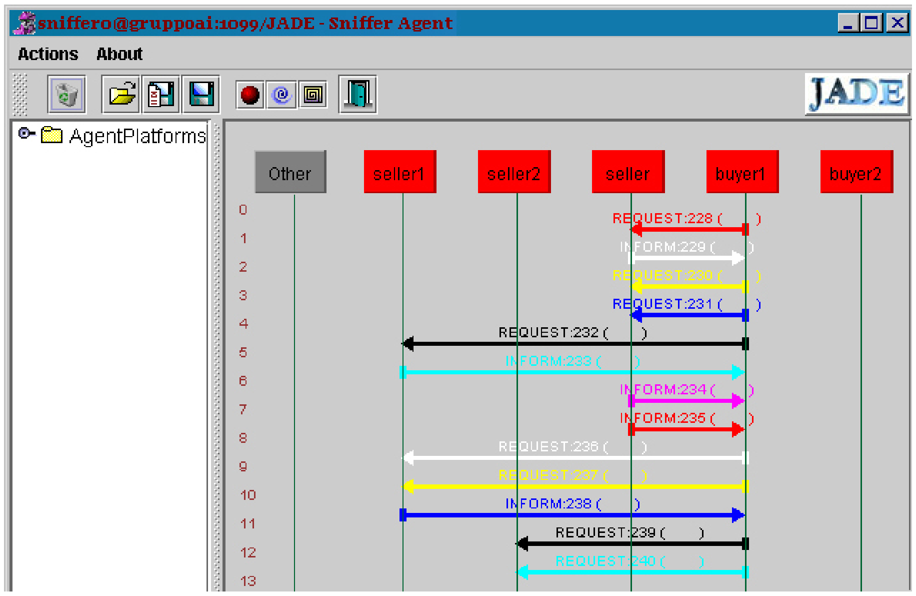
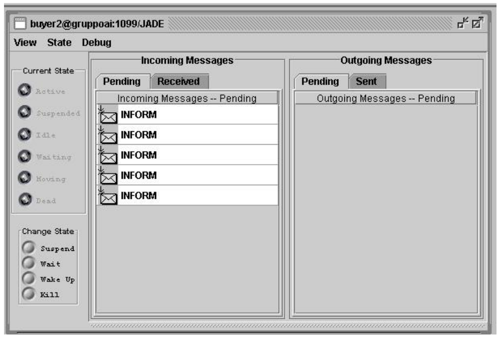


Fig. 6. Output of the JADE sniffer agent.

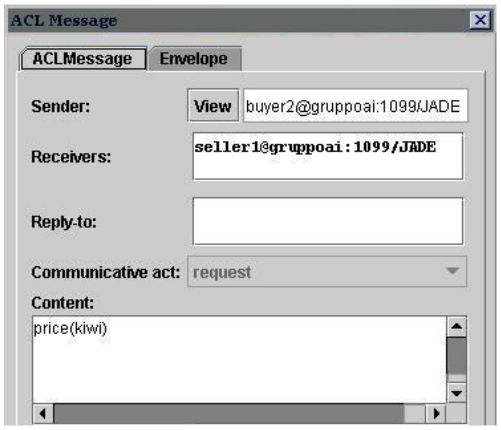
The state of the agents' mailboxes can be inspected thanks to the introspector agent, a GUI too. Figure 7 shows the state of the mailbox of `buyer2`. This screen-shot was taken at the beginning of the simulation; all the `INFORM` messages shown are answers to price requests previously issued by `buyer2` to the sellers.



```
Incoming Messages -- Pending
INFORM
INFORM
INFORM
INFORM
INFORM
Outgoing Messages -- Pending
```

Fig. 7. JADE window showing the communication among agents.

Details on the messages exchanged can also be inspected. Figure 8 shows the request for the price of kiwi sent by `buyer2` to `seller1`. Figure 9 shows the answer to this request.



Sender: buyer2@gruppoai:1099/JADE

Receivers: seller1@gruppoai:1099/JADE

Reply-to:

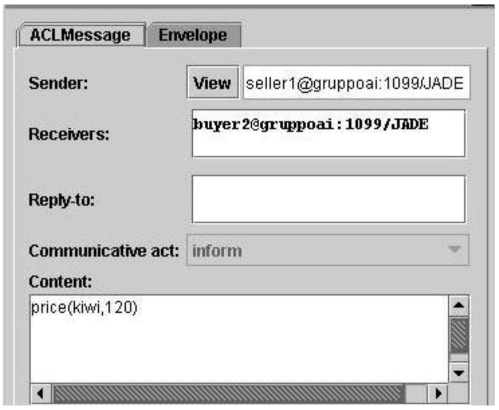
Communicative act: request

Content:

price(kiwi)

Fig. 8. Price request from `buyer2` to `seller1`.

The execution and monitoring of the prototype, obtained by exploiting the tools provided by JADE, allow the developer to verify whether the agents work well according



Sender: seller1@gruppoai:1099/JADE
Receivers: buyer2@gruppoai:1099/JADE
Reply-to:
Communicative act: inform
Content:

```
price(kiwi,120)
```

Fig. 9. Price answer from `seller1` to `buyer2`.

to their intended behaviour. The sniffer agent also allows to save into a file the messages exchanged by the agents. When that file is loaded by the user through the sniffer agent, it is possible to view the details of each message by clicking on the arrow representing the exchange of a message. A user can then check if the messages have been sent in the expected order (for example, that all the buyers ask for the price of fruit first, and start buying fruit afterwards), by viewing the content of every single message displayed in the canvas of the agent sniffer. Without the integration of tuProlog into JADE, verifying the correctness of communication between agents implemented in Prolog could only be done by hand: the developer had to put breakpoints in his/her code or he/she had to write messages on the standard output or in a separate file in order to follow what was going on during the prototype execution. CaseLP offers graphical debugging tools more sophisticated than this “by-hand” inspection. Nevertheless, the adoption of the instruments already provided by a standard, FIPA-compliant and open-source platform, represents an improvement to the use of proprietary instruments offered by CaseLP.

5 Conclusions and future work

In this paper we have discussed the integration of a Prolog implementation, tuProlog, into the DCaseLP prototyping environment. Recently, the integration of the DyLOG executable logic-based language into DCaseLP has been designed, thus enriching the set of specification/implementation languages supported by DCaseLP. The integration of tuProlog into DCaseLP represents another step forward in this direction and gives us two main advantages:

1. It allows us to re-use the work previously done with CaseLP regarding the study and the definition of semi-automatic translators from high-level specification languages into Prolog-based communicative agents.
2. It represents a relevant example that we can follow to implement a new DyLOG interpreter in Java, and to integrate this new interpreter into DCaseLP.

Currently, the two advantages above cannot be exploited in practice because we did not have time enough to implement all the components, so we need to make the integration of DyLOG and the languages provided by CaseLP usable. Our future efforts will be channelled in this implementative direction, in order to make DCaseLP the integrated environment for engineering and prototyping heterogeneous MAS that it was intended to be.

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